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DOCUMENT-IDENTIFIER: US 6011606 A
TITLE: Parallel field active matrix type liquid crystal display using liquid crystal having particular electrical properties

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Abstract Text (1):
An active matrix type liquid crystal display apparatus having a pair of substrates sandwiching a liquid crystal layer. A group of electrodes form a matrix of pixels and an active device, each of the group of electrodes being provided between the liquid crystal and one of the substrates. The electrodes are arranged so as to apply an electric field, mainly parallel to the substrates. The resistivity of the liquid crystal layer is lower than or equal to 1.times.10.sup.14 .OMEGA..multidot.cm. The relationship between the elasticity constant K2 and the dielectric anisotropy .DELTA..epsilon. satisfies the equation K.sub.2 /.DELTA..epsilon.<9.0.times.10.sup.-8 [dyn]. Further, a relationship between a gap between a pixel electrode and a common electrode and a gap between the pair of substrates is satisfied.

Brief Summary Text (9):
According to a first aspect of the present invention, the present invention comprises a pair of substrates, at least one of which is transparent; a liquid crystal layer inserted between the substrates; an orientation film provided between the liquid crystal layer and at least one of the pair of substrates and on an inner side of said at least one substrate; a scanning signal electrode, an image signal electrode, a pixel electrode and an active device, each provided between the liquid crystal layer and the at least one substrate; and polarization means provided on the outer side of the substrates, for changing a optical characteristic according to an orientation state of the liquid crystal; each of said electrodes being constructed so as to apply an electric field, mainly parallel to said substrates, against said liquid crystal layer, and being connected to an external control means for controlling optionally the applied electric field according to the display pattern; wherein said electrode lies between at least two dielectric layers disposed above and below the electrode, and wherein the resistivity of said liquid crystal is higher than or equal to 1.times.10.sup.9 .OMEGA..multidot.cm and lower than or equal to 1.times.10.sup.13 .OMEGA..multidot.cm.

Brief Summary Text (23):
By providing the electrode between at least two dielectric layers disposed above and below the electrode, and by making the resistivity of the liquid crystal lower than or equal to 1.times.10.sup.13 .OMEGA..multidot.cm, as described in the first aspect, it is possible to increase the numerical aperture. The reason for this will be explained hereinafter. In generating the horizontal electric field, an opaque metal electrode is used. It is, therefore, impossible to realize a numerical aperture larger than the one of the prior art. The basic method of solving this problem is to enlarge the gap between the electrodes. However, a new problem may arise due to such enlargement of the gap. The disturbance of the orientation occurs due to static electricity, because the volume of the liquid crystal decreases further. To provide

an auxiliary capacitance for each pixel brings about a deterioration of the numerical aperture. However, if the resistance of the liquid crystal is low, the disturbance of the orientation due to static electricity is small. Therefore, this provides a very effective solution. By this means, the domain around a spacer bead is also improved. In the conventional active matrix type liquid crystal display apparatus, it is required to use a liquid crystal with a high resistivity of at least 1.times.10.sup.13 .OMEGA..multidot.cm, preferably, 1.times.10.sup.14 .OMEGA..multidot.cm, in order to apply a sufficient voltage even during a non-selected period of time. In the horizontal electric field method the dielectric, except for the liquid crystal, such as a glass or other insulation film, acts to hold a capacitance to obtain the voltage hold ratio necessary for proper operation. By experiments, we found that even a liquid crystal with a resistivity of 1.times.10.sup.10 .OMEGA..multidot.cm has a high voltage hold ratio (frame frequency: 60 Hz) of more than 90%. However, compared to a conventional method, such as the TN method, the total capacitance, including the capacitance of the liquid crystal and the hold capacitance, is smaller in magnitude in the horizontal electric field method and is susceptible to the effect of static electricity. Not only the problem of static electricity, but also an increase in the drive voltage is brought about by an enlargement of the gap between the electrodes.

Brief Summary Text (25):
As described in connection with the fourth aspect, by using a liquid crystal chemical compound represented by a general chemical formula (I), in which a cyano group, trifluoromethyl group, trifluoromethoxyl group or nitro group is included as an end group, we obtained an effective liquid crystal with a large numerical aperture. Namely, by a decrease in the resistivity, the static electricity can be prevented, and at the same time the drive voltage can be decreased. The decreasing of the resistivity is further effective for a small viscosity necessary for high-speed response. The liquid crystal which can not increase its resistivity, such as cyano groups, can be used for the display apparatus, because liquid crystals with lower resistivity show a high voltage hold ratio in the horizontal electric field method. Therefore, the margin of the kind of the liquid crystal to be used remarkably increases. ##STR3##

Brief Summary Text (28):
When using a liquid crystal having a negative dielectric anisotropy, by including a liquid crystal chemical compound represented by a general chemical formula (II), in which a cyano group, trifluoromethyl group, trifluoromethoxyl group or nitro group is included as an end group, as described in connection with the fifth aspect, we obtained an effective liquid crystal with a large numerical aperture. Namely, by a decrease in the resistivity, the static electricity can be prevented, and at the same time the drive voltage can be decreased. The decreasing of the resistivity is further effective for a small viscosity necessary for high-speed response. The liquid crystal which can not increase its resistivity, such as the cyano groups, can be used for the display apparatus, because liquid crystals with a lower resistivity show a high voltage hold ratio in the horizontal electric field method. Therefore, the margin of the kind of liquid crystal to be used remarkably increases. ##STR4##

Detailed Description Text (6):
The resistivity of the liquid crystal is 7.6.times.10.sup.12, and undesirable conditions of orientation due to static electricity do not occur. An active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (10):
The resistivity of the liquid crystal is 7.6.times.10.sup.12 .OMEGA..multidot.cm, and undesirable conditions of orientation due to static electricity do not occur. An active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (14):

The resistivity of the liquid crystal is 3.3.times.10.sup.11 .OMEGA..multidot.cm, and the undesirable conditions of orientation due to static electricity do not occur. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (18):
The resistivity of the liquid crystal is 2.4.times.10.sup.10 .OMEGA..multidot.cm, and the undesirable conditions of orientation due to static electricity do not occur. The relation between the elasticity constant K.sub.2 and the dielectric anisotropy .DELTA..epsilon., is made to be 8.5.times.10.sup.-8 .OMEGA..multidot.cm. Furthers the drive voltage can be established to be 5 V or less. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (22):
The resistivity of the liquid crystal is 9.3.times.10.sup.9 .OMEGA..multidot.cm, and the undesirable conditions of orientation due to static electricity do not occur. The relation between the elasticity constant K.sub.2 and the dielectric anisotropy .DELTA..epsilon., is made to be 5.4.times.10.sup.-8 .OMEGA..multidot.cm. Further, the drive voltage can be established to be 5 V or less. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (27):
The resistivity of the liquid crystal is 8.1.times.10.sup.10 .OMEGA..multidot.cm, and the undesirable conditions of orientation due to static electricity do not occur. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (31):
The resistivity of the liquid crystal is 2.2.times.10.sup.10 .OMEGA..multidot.cm, and undesirable conditions of orientation due to static electricity do not occur. The relation between the elasticity constant K.sub.2 and the dielectric anisotropy .DELTA..epsilon. is made to be 4.6.times.10.sup.-8 .OMEGA..multidot.cm. Further, the drive voltage can be established to be 5 V or less. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (35):
The resistivity of the liquid crystal is 6.2.times.10.sup.10 .OMEGA..multidot.cm, the undesirable conditions of orientation due to static electricity do not occur. The relation between the elasticity constant K.sub.2 and the dielectric anisotropy .DELTA..epsilon. is made to be 2.9.times.10.sup.-8 .OMEGA..multidot.cm. Further, the drive voltage can be established to be 5 V or less. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (39):
The resistivity of the liquid crystal is 8.8.times.10.sup.-9 .OMEGA..multidot.cm, and undesirable conditions of orientation due to static electricity do not occur. The relation between the elasticity constant K.sub.2 and the dielectric anisotropy .DELTA..epsilon. is made to be 2.3.times.10.sup.-8 .OMEGA..multidot.cm. Further, the drive voltage can be established to be 5 V or less. As a result, an active matrix

type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (43):
The resistivity of the liquid crystal is 8.6.times.10.sup.11 .OMEGA..multidot.cm, and undesirable conditions of orientation due to static electricity do not occur. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is-established, in which an inversion of gradation does not occur over more than 60 degrees in the up and down direction, and more than 60 degrees in the right and left direction.

Detailed Description Text (47):
The resistivity of the liquid crystal is 7.2.times.10.sup.10 .OMEGA..multidot.cm, and undesirable conditions of orientation due to static electricity do not occur. As a result, an active matrix type liquid crystal display apparatus, having both a broad visual field and a large numerical aperture, is established, in which a inversion of gradation does not occur over more than 60 degrees in the up and down directions and more than 60 degrees in the right and left direction.

CLAIMS:

wherein at least one of said electrodes is disposed between at least two dielectric layers disposed above and below the at least one of said electrodes, and wherein the resistivity of said liquid crystal layer is higher than or equal to 1.times.10.sup.9 .OMEGA..multidot.cm and lower than or equal to 1.times.10.sup.13 .OMEGA..multidot.cm,

wherein at least one of said electrodes is disposed between at least two dielectric layers disposed above and below the at least one of said electrodes, and wherein the resistivity of said liquid crystal layer is higher than or equal to 1.times.10.sup.9 .OMEGA..multidot.cm and lower than or equal to 1.times.10.sup.13 .OMEGA..multidot.cm,

wherein at least one of said electrodes is disposed between at least two dielectric layers disposed above and below the at least one of said electrodes, wherein the resistivity of said liquid crystal layer is higher than or equal to 1.times.10.sup.9 .OMEGA..multidot.cm and lower than or equal to 1.times.10.sup.13 .OMEGA..multidot.cm, and wherein, when the dielectric anisotropy of the liquid crystal layer is positive, a rubbing angle is set to an angle more than or equal to 1 degree and less than or equal 20 degrees relative to the direction of the electric field, and when the dielectric anisotropy of the liquid crystal is negative, the rubbing angle is set to an angle more than or equal to 1 degree and less than or equal to 10 degrees relative to the direction of the electric field.

wherein at least one of said electrodes is disposed between at least two dielectric layers disposed above and below the at least one of said electrodes, wherein the resistivity of said liquid crystal layer is higher than or equal to 1.times.10.sup.9 .OMEGA..multidot.cm and lower than or equal to 1.times.10.sup.13 .OMEGA..multidot.cm, and wherein the transmission axis of said polarization means is set to an angle deviated more than or equal to 1 degree from an initial orientation direction of the liquid crystal layer to a rotation direction of the axis of a molecule of the liquid crystal layer due to the electric field.

wherein said liquid crystal layer has a resistivity which is sufficient to enable display by the liquid crystal display device and which is no greater than 1.times.10.sup.13 .OMEGA..multidot.cm, and wherein said liquid crystal layer has a composite material made to include a liquid crystal chemical compound represented by a general chemical formula (I), ##STR7## wherein in the formula (I), X.sub.1, X.sub.2 and X.sub.3 are selected from a group consisting of fluoro group, cyano group, trifluoromethyl group, trifluoromethoxyl group, nitro group and hydrogen atom, not all three X.sub.1, X.sub.2 and X.sub.3 being a hydrogen atom; R is selected from a group consisting of alkyl group and alkoxyl group having the carbon number 1 to 10 which can be substituted; Ring A is selected from a group consisting

of cyclohexane ring, benzene ring, dioxane ring, pyrimidine ring, and [2,2,2]-bicyclohexane ring, Z is selected from a group consisting of single bonding, ester bonding, ether bonding, methylene, and ethylene; and n is 1 or 2.

wherein said liquid crystal layer has a resistivity which is sufficient to enable display by the liquid crystal display device and which is no greater than 1.times.10.sup.13 .OMEGA..multidot.cm, and wherein said liquid crystal layer has a composite material made to include a liquid crystal chemical compound represented by a general chemical formula (II), ##STR8## wherein in the formula (II), X.sub.1 and X.sub.2 are selected from a group consisting of fluoro group, cyano group, trifluoromethyl group, trifluoromethoxyl group, nitro group and hydrogen atom, not both X.sub.1 and X.sub.2 being a hydrogen atom; R is selected from a group consisting of alkyl group and alkoxyl group having the carbon number 1 to 10 which can be substituted; Ring A is selected from a group consisting of cyclohexane ring, benzene ring, dioxane ring, pyrimidine ring, and [2,2,2]-bicyclohexane ring, Z is selected from a group consisting of single bonding, ester bonding, ether bonding, methylene, and ethylene; and n is 1 or 2.

wherein said liquid crystal layer has a resistivity which is sufficient to enable display by the liquid crystal display device and which is no greater than 1.times.10.sup.13 .OMEGA..multidot.cm, and wherein, when the dielectric anisotropy of the liquid crystal layer is positive, a rubbing angle is set to an angle more than or equal to 1 degree and less than or equal 20 degrees relative to the direction of the electric field, and when the dielectric anisotropy of the liquid crystal is negative, the rubbing angle is set to an angle more than or equal to 1 degree and less than or equal to 10 degrees relative to the direction of the electric field.

wherein said liquid crystal layer has a resistivity which is sufficient to enable display by the liquid crystal display device and which is no greater than 1.times.10.sup.13 .OMEGA..multidot.cm;